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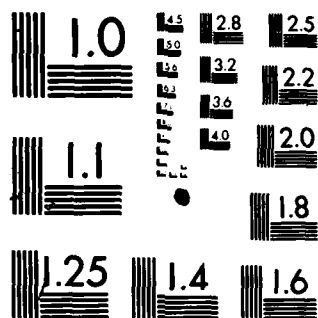JUN 82 I G SCOTT
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MELBOURNE, VICTORIA

Materials Technical Memorandum 382

A SPECTRUM ANALYSER FOR ACOUSTIC EMISSION

I.G. SCOTT

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A SPECTRUM ANALYSER FOR ACOUSTIC EMISSION

by

I.G. SCOTT

Summary

A parallel filter, spectrum analyser is described
which can be made using simple circuits and cheap, readily
available components.

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1. INTRODUCTION

Frequency analysis of acoustic emission (AE) involves the capture and analysis, or real-time analysis, of an impulsive or non-repetitive signal. The present ARL procedure involves the use of a transient recorder and conventional heterodyne spectrum analyser, and no more than one event per five seconds can be handled. Even with the adoption of a strict sampling procedure, much information is lost, particularly during the important periods of intensive AE activity.

Upton (1977) discussed the use of the heterodyne analyser, of parallel analogue or digital filters, and of the FFT algorithm. Commercial equipment based on these principles is available but expensive. Clark and Mathieson (1977), and Graham (1979), used matched sets of band-pass filters whose centre frequencies were related by a fixed ratio. This method of spectral analysis is fast, provides an output suitable for handling by a computer and, by restricting the number of bands, suppresses much unwanted detail in the spectrum. It was chosen for laboratory development and was constructed from available cheap components.

2. SYSTEM SPECIFICATION

The response time of the parallel filter system is determined by the filter with the lowest centre frequency. An approximation to filter response time, T, is given by

$$T = \frac{1}{B} = \frac{Q}{f_o}$$

where B is the bandwidth and f_o is the centre frequency; for $f_o = 0.1$ MHz and $Q = 5$, $T = 50\mu s$. Allowing (say) 25µs for the operation of logic devices results in a minimum recording period of 75µs. For an aluminium specimen (longitudinal wave velocity = 6.32 mm/µs) of width 63.2 mm, the first reflected wave can arrive 20µs after the direct wave. However, for many laboratory-size specimens, ring-downs lasting about 1ms have been observed. Hence, 1ms was chosen as the recording period. (NOTE:- it is commonly observed that spectra are dominated by specimen characteristics).

It was planned to cover the frequency range of 0.1MHz to 1MHz. Assuming that the filter cross-over points occur at -10dB, then, for $Q = 5$, the centre frequencies are determined (see below).

The above preliminary considerations form the basis for the system specification, viz.

(i)   System operation shall be triggered when the leading
      edge of an AE event exceeds the variable (but preset)
      threshold level.

(ii) The duration of the recording period shall be 1ms.

(iii) Spectral data shall be read out to a plotter such that
      the total sweep time is 2s (but provision shall be made
      for reduction of this time at a later date).

(iv) System logic shall provide for remote pen control along
      with shifting of the base line after the completion
      of each record.

(v)   Acceptance of additional AE signals during the sweep
      time is not permitted.

(vi) The centre frequencies of the filters shall be :
      0.100, 0.147, 0.215, 0.316, 0.464, 0.681 and 1.00 MHz.

(vii) The peak value of output during the 1ms period, from
      each individual filter, shall be recorded.

3.   SYSTEM DETAIL

Given a workable specification, system detailing becomes
relatively straight forward and the functions of the system elements
can be tabulated (Table 1). Some interesting features are :

(i)   **Filter design**: In many respects, the use of a passive
      filter is desirable but extensive experience with active
      filters led to a satisfactory design using the µA 715
      operational amplifier. The circuit for the 0.464 MHz
      filter is shown in Figure 1, compensation appropriate to
      a gain of 10 being applied. Minor problems with the
      1 MHz filter were overcome by using unequal capacitors,
      which causes slight asymmetry of the response curve.

(ii) **Plotter control**: Three interconnected counter-multiplexer
      pairs (DM 7493/DM 7501) were used to provide a time-base,
      to select filter-inputs and to shift the base line of the
      display. Seven output levels resulted but, in order
      to provide zero reference, the 0.1 MHz filter was deleted.

          The clock runs continuously; thus one can ensure
      that the counter is always started by an upward-going
      signal. The clock is connected to the counter via a
      synchronising circuit. A pulse, generated from the input

signal, and marginally longer than the clock pulse, is
fed to an AND gate along with the clock pulse. The
output drives an analogue switch, which connects clock
and counter.

At the end of the sweep a CLEAR pulse is
derived from one of the multiplexers. However, reliable
operation was not obtained until a signal was applied to
the RESET of the counter. A PAUSE between plotter sweeps
is provided by controlling the length of the CLEAR pulse.

(iii) Sample-and-hold circuits: The CLEAR pulse is used to
sequentially discharge the condensers associated with
the sample-and-hold circuits (LM 398) and ready them for
acceptance of the next signal. The PEAK condenser is
charged to a voltage proportional to the peak output
from the filter band (the effect of accumulated small
signals occurring between recording periods is disregarded).
At the conclusion of the recording period, an ACQUIRE
pulse is generated and the condenser voltage is held
(or charge is stored) during the read-out or sweep period.
If more than one event occurs during the recording period
(which is unlikely), then the maximum value of the signal
in the filter band will be recorded. The analyser logic
is shown in Figure 2.

4. DISCUSSION OF SYSTEM FEATURES

A continuous wave signal was input to the analyser and
several single sweeps, each at a fixed frequency, were recorded.
The resulting calibration is shown in Figure 3. Some unusual
effects arise from the relationship between input and filter
frequencies. However, for a given input, the output is unique. If
improved frequency definition is desired, or if the amplitude of the
cross-over point is decreased, then more filters, each having increased
Q, will be needed to cover the same range. Some problems in filter
design can be anticipated. Also, the output pattern will be changed
and the present simplicity of presentation will be lost.
Alternatively, it may be possible to develop the Collocott (1980)
idea of a frequency discriminator having ultra-sharp response.

The system is intended for use over comparatively short
periods of time - say about 30 mins. For most of the time only
occasional AE events will occur, but at least one period of intense
AE activity per test is anticipated. During the former period, small
signals (noise or signals below trigger level) may collect on the
PEAK condenser, but these are expected to leak away and cause
minimal error. During the latter period, only a sampling of events

is possible (even when recording and sweep times are reduced - see next paragraph). Some analysis of multiple events will be made and some very large events will cause the system to trigger more than once. If a saturation event rate of 1000 s^{-1} is assumed, the probability of occurence of an unidentified false signal is small. Clearly, a careful analysis of results is needed at high event rates.

Increasing the sampling rate for periods of intense AE activity may require two major changes. The first involves reduction of the recording time - although this is possible from a system stand-point, erroneous readings may result. Ring-down time is determined by the specimen-transducer-pre-amplifier combination and should be less than the recording time if multiple triggerings from the same event are to be avoided. For most purposes assumption of a recording time of 1ms is reasonable. The second major change requires the use of a read-out device (unspecified) which permits rapid acquisition of information. The clock pulse, CLEAR pulse and two sweep control pulses all need to be shortened (during system development this was done on several occasions to permit use of a CRO display).

5. FUTURE DEVELOPMENTS

There are two aspects for future development - the first concerns different types of read-out device which would provide faster read-out while the second refers to different uses of the system and to some extent involves changes in specification.

Read-out time can be decreased to a limited extent by the use of rapid response plotters. Alternatively, signals can be recorded on analogue tape which is subsequently replayed at slower speed - presently the speed can be reduced by a factor of sixty. For very fast read-out, a digital approach is needed - this is heavy-handed in concept but may well turn out to be simple in application.

In view of the statistical nature of AE, it may be efficient to average spectra before read-out. The assumes that all spectra are similar, which has yet to be disproved. Sampling can be conducted in several ways: over a fixed period (say 10ms), over the whole of a test or for a chosen number of events. In all cases a marked relaxation of the present read-out requirement would result.

Finally, Graham (1979) has found that the use of a spectral parameter (e.g. ratio of amplitudes at two chosen frequencies) yields promising results. By using a logarithmic presentation of

output, ratios are obtained by subtraction. Provision has been made for the insertion of a log amplifier module in the present analyser.

6. CONCLUSIONS

The feasibility has been demonstrated of building a parallel filter, spectrum analyser using simple circuits and cheap, readily available components. Unwanted detail in spectra is suppressed.

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6. CONCLUSIONS

The feasibility has been demonstrated of building a parallel filter, spectrum analyser using simple circuits and cheap, readily available components. Unwanted detail in spectra is suppressed.

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TABLE 1: FUNCTIONS OF SYSTEM ELEMENTS

ELEMENT	FUNCTION
MULTIPLEXER	(1) Produce 8-step staircase voltage to serve as time base for plotter display (horizontal axis)
	(2) Select in turn, properly synchronised outputs from 7 sample-and-hold circuits (vertical axis)
	(3) Shift horizontal display vertically after each recorded signal
PLOTTER CONTROL	(1) Synchronise multiplexer operation with input signal
	(2) Initiate plotter pen operation
	(3) Operate PEN LIFT at completion of plot
ANALYSER LOGIC	(1) Compare input signal with threshold and produce 1ms logic pulse
	(2) Control sampling of filter output
	(3) Read and plot peak filter output; INHIBIT input during plotting
	(4) Discharge PEAK and HOLD capacitors at completion of plot
ANALYSER	(1) Sort signal frequencies using parallel filter bank
	(2) Sample and hold peak signal amplitude during 1ms period from each filter
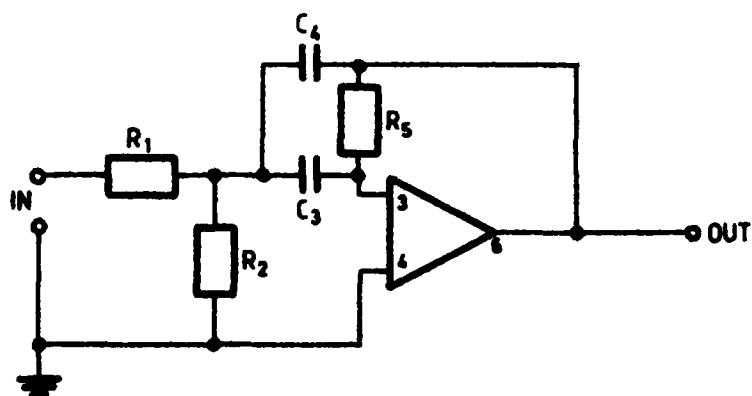
μA 715 HC

Comp 1-9 100 pFd
     7-10 220 pFd

+ Vcc 8 15V
− Vcc 5 15V

(each bypassed 0.1 mFd at pins)

R_1 8.2 k ohm
R_2 100 ohm
R_5 22 k ohm
C_3 220 pFd
C_4 220 pFd

FIG. 1 CIRCUIT FOR NOMINAL 0.464 M Hz FILTER
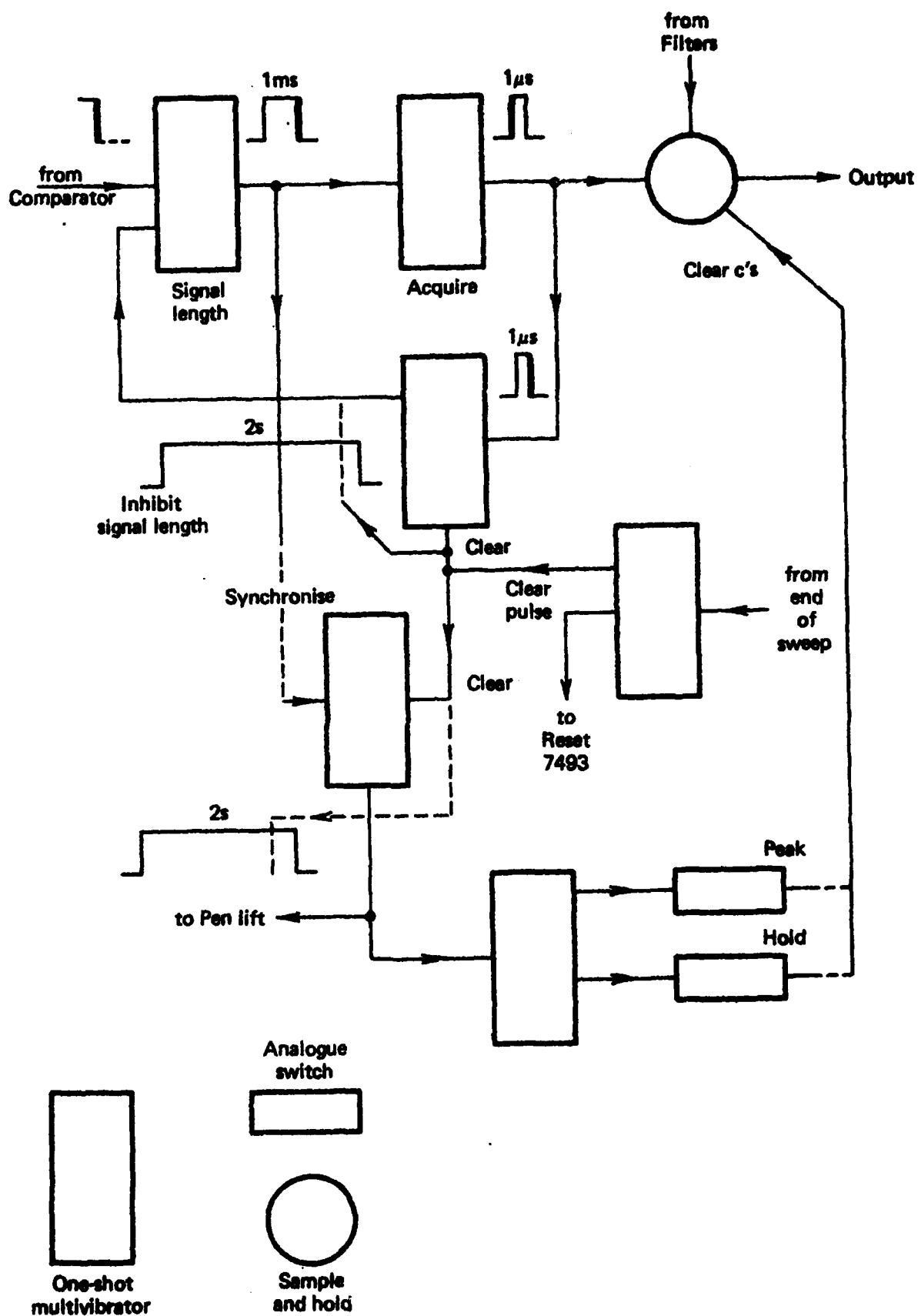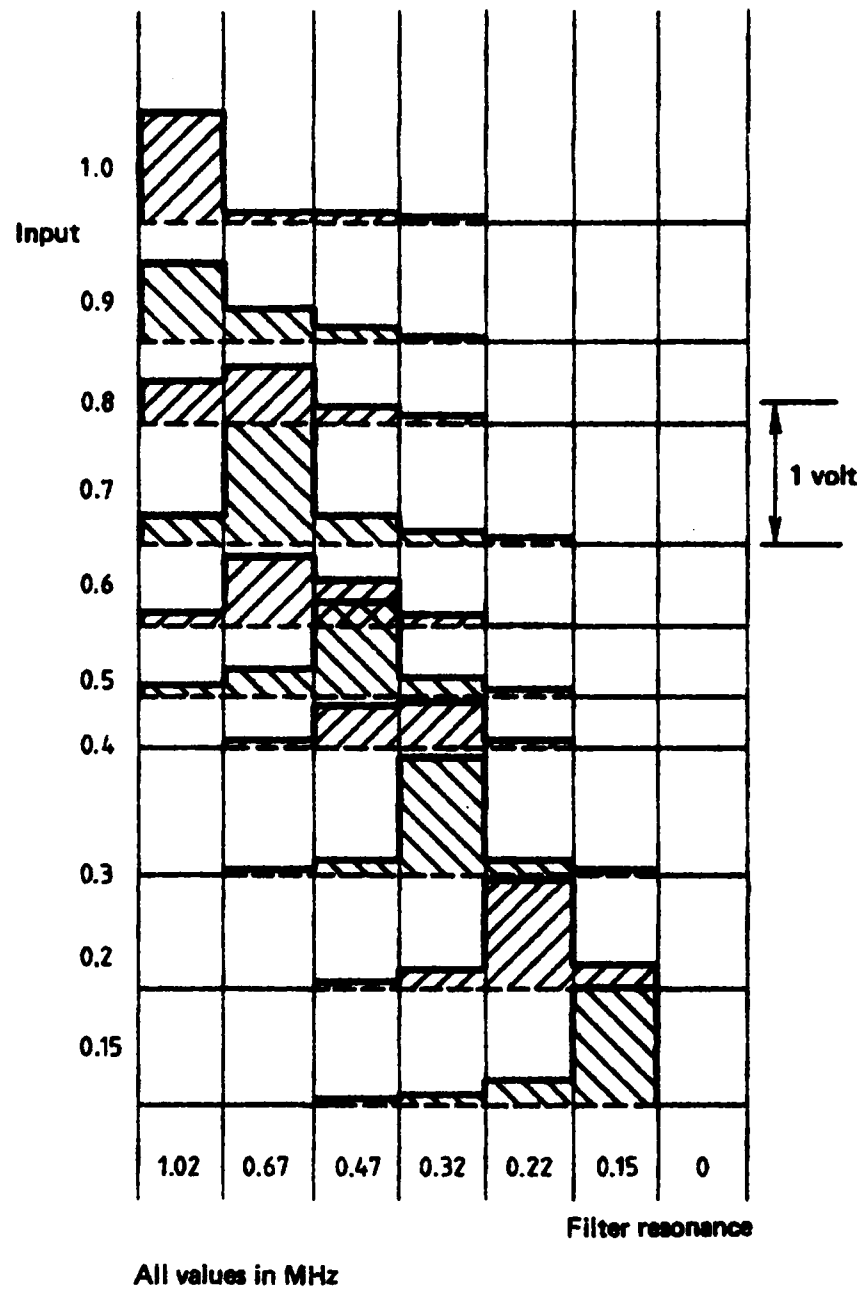
FIG. 2 ANALYSER LOGIC

FIG. 3   CALIBRATION OF SPECTRUM ANALYSER

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16. Abstract

A parallel filter, spectrum analyser is described which can be made using simple circuits and cheap, readily available components.

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